

Ultra Low Emission Vehicles Guide 2016



FOREWORD



Ultra low emission vehicle (ULEV) technology has moved on considerably since we last published the Electric Car Guide in 2011. What is most significant, perhaps, is that we are seeing ever-greater choice in technology and models. What was once a choice of hybrids and battery electric vehicles has been expanded to plug-in hybrids, alternative fuels and, most recently, hydrogen fuel cell vehicles. It is for this reason that we have renamed this document the ULEV Guide. Along with the dramatic and relentless development of next generation petrol and diesel engines, the choice for consumers will only get better.

The automotive industry invests huge amounts developing, manufacturing and bringing to market vehicles that are cleaner and more fuel-efficient yet still meet functional motoring needs and are fun to drive.

This is as true of the UK automotive industry as any other and the UK market for these technologies is accelerating faster than any other in Europe. The demand for alternatively-fuelled vehicles grew 40.3% last year, securing its biggest ever market share of 2.8%. Plug-in hybrids experienced phenomenal growth, with new registrations more than doubling, while pure electric vehicles saw an uplift of around 50%. Increasing numbers of private motorists and fleet operators reap the environmental and cost benefits of ULEVs but there is still a long way to go if we are to achieve government's 2040 target of every new car being an ULEV.

Industry and government are working together to develop and implement a raft of measures to make the UK a global leader in low carbon technology and solutions. The Automotive Council, a beacon of collaboration envied by other countries, ensures that industry activities, technology roadmaps and government strategy are aligned to make the UK the location of choice for the development, demonstration and deployment of low carbon technologies. The Advanced Propulsion Centre, a £1 billion initiative jointly funded by government and industry, helps turn low carbon propulsion concepts into commercial, market-ready products developed and produced in the UK. Hitherto, some £290 million has been committed to 17 collaborative R&D projects that will save more than 17 million tonnes CO₂ emissions while also creating or securing at least 5,300 jobs in the UK.

While there are well-defined technology roadmaps that chart the sector's expected progression to evermore advanced low carbon technologies, it is also important to inform the wider industry and its stakeholders about the increasingly complex world of ULEVs. This guide sets out to do just that; to explain the types of ULEV available, their respective benefits and also the practical information necessary, such as charging or refuelling, batteries and running costs.

Mike Hawes
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The Society of Motor Manufacturers and Traders

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GLOSSARY

Vehicle glossary

ABBREVIATION	DESCRIPTION	EXPLANATION
ULEV	Ultra Low Emission Vehicle	A vehicle that uses low carbon technologies and emits less than 75g of CO ₂ /km from the tailpipe and is capable of operating in zero tailpipe emission mode for a range of at least ten miles.
EV	Electric Vehicle Alternative description: <ul style="list-style-type: none">• Electric car	A vehicle powered, in part or in full, by an electric motor and battery that can be plugged into the mains or a chargepoint. In short, any vehicle that can be plugged in.
BEV	Battery Electric Vehicle Alternative descriptions: <ul style="list-style-type: none">• Electric• All electric• Pure electric vehicle (Pure EV)• Fully electric	A vehicle powered solely by a battery charged from the electricity grid. Currently, typical pure electric cars have a range of approximately 100 miles or more.
PHEV	Plug-in Hybrid Electric Vehicle Alternative descriptions: <ul style="list-style-type: none">• Plug-in hybrid vehicle (PHV)	A vehicle with a plug-in battery and an internal combustion engine (ICE). Typical PHEVs will have a pure-electric range of around 30 miles. After the pure-electric range is used, the vehicle reverts to the benefits of full hybrid capability (using both battery power and ICE) without range compromise.
E-REV	Extended-Range Electric Vehicle Alternative descriptions: <ul style="list-style-type: none">• Range extended electric vehicle (RE-EV)• REX	A vehicle powered by a battery with an ICE powered generator on board. E-REVs are like BEVs but with a shorter battery range of between 40 and 100 miles. Range is extended by an on board generator providing many additional miles of mobility.
FCEV	Fuel Cell Electric Vehicle	A vehicle that uses hydrogen gas as a fuel, which is stored in a compact, strong, but lightweight pressure tank. Power is generated by the fuel cell stack and is used to drive the FCEV's electric motor, with additional power supplied when needed from a secondary battery. This battery is also used to store additional short-term energy recovered from regenerative braking. FCEVs typically have ranges of 300 miles or more and emit only water vapour from their exhaust.

Electric quadricycle		An 'electric quadricycle' is a four-wheeled vehicle that is categorised and tested in a similar way to a moped or three-wheeled motorcycle. Quadricycles typically do not have the same performance as EVs and under EU legislation, electric quadricycles are not required to be tested to the same high standards as vehicles which have gone through the 'type approval' process (such as crash tests). This document does not include quadricycles, bikes mobility vehicles or other forms of electric vehicles when referring to EVs that aren't cars.
Hybrids	Hybrid	A hybrid vehicle is powered by an ICE. It uses a battery and electric motor to capture and re-use braking energy, supplementing direct power from the ICE. The power source is selected automatically by the vehicle, depending on speed, engine load and battery charge level. This battery cannot be plugged in; its charge is maintained by regenerative braking supplemented by ICE generated power.
	Alternative descriptions: <ul style="list-style-type: none"> • Hybrid electric vehicles (HEV) • Normal hybrid • Standard hybrid 	
	Full Hybrid	A full hybrid has the same attributes as a hybrid (above) plus the ability to operate solely on battery power although the battery cannot be plugged in.
	Mild Hybrid	A mild hybrid vehicle cannot be plugged in, nor driven solely on battery power.
	Micro Hybrid	A micro hybrid normally employs a stop-start system and regenerative braking which charges the vehicle's 12V battery.
	Stop-start Hybrid	A stop-start system shuts off the engine when the vehicle is stationary. An enhanced starter is used to support the increased number of engine starts required in a stop-start vehicle.
AFV	Alternatively-Fuelled Vehicle	Any vehicle which is not solely powered by traditional fuels (i.e. petrol or diesel) is referred to as alternatively-fuelled.
ICE	Internal Combustion Engine	Petrol or diesel engine, including those adapted to operate on alternate liquid or gaseous fuels.



Additional terms

ABBREVIATION/TERM	DESCRIPTION	EXPLANATION
PiCG	Plug-in Car Grant	The government grant to reduce the purchase cost of eligible pure electric, plug-in hybrid and fuel cell electric cars (currently to a maximum of £4,500 from March 2016). ¹
PiP	Plugged-in Places	The government scheme to trial a range of different approaches to charging networks in regions around the UK which helped roll-out a UK-wide infrastructure network. ² Following the completion of the Plugged-in Places (PiP) scheme, most regions within the UK transitioned to private operators (such as Chargemaster and Bluepoint London).
Range anxiety		Range anxiety refers to the fear people have about the distance an EV can cover and the concern that the range may not be sufficient to reach the intended destination. This document aims to allay such fear by explaining how EVs can meet the needs of many journeys.

¹ <http://www.dft.gov.uk/pgr/sustainable/olev/grant1/>

² <https://www.gov.uk/government/publications/plugged-in-places>



Battery and charging glossary

TERM	DESCRIPTION	EXPLANATION
Charge times and cycle	Charge time Alternative terms: <ul style="list-style-type: none"> • EV charge time • Recharge time 	The time it takes to charge an EV. EVs require different lengths of time to charge according to the size of the battery, how much charge is left in the battery before charging and the type of charger used. The information below is based on the example of a pure electric car to illustrate the most extreme charge time. PHEVs and E-REVs will typically have smaller batteries and so take less time to charge.
	Cycle Alternative term: <ul style="list-style-type: none"> • Name plate cycle 	A cycle is the battery charge from completely flat (0% charge) to full (100% charge) and back to flat (0% charge).
Types of charge	Standard charge (up to 3kW) Alternative terms: <ul style="list-style-type: none"> • Slow charge • Normal charge 	Standard charge is available in all UK homes. ³ It will take approximately six to eight hours to charge the average pure electric car. ⁴

³ It is recommended to install a home charging unit on a dedicated EV circuit. This will ensure the circuit can manage the electricity demand from the vehicle and that the circuit is activated only when the charger communicates with the vehicle, known as the 'handshake'. If you are charging outdoors, an external weatherproof socket can also be installed.

⁴ For this example we have assumed the vehicle is a standard sized EV and that the battery is completely empty before recharging, and that a dedicated charger is used. However, charging can take longer if the vehicle is connected to standard 13A domestic sockets (such charging cables will limit the amperage draw by the car in order to reduce the load on the electricity circuit and ensure maximum safety for the user).

	Fast charge (7-22kW) Alternative term: <ul style="list-style-type: none"> Faster charge 	7kW domestic chargepoints are widely available for use with 32A circuits. Higher power fast charge will normally occur at dedicated charge bays rather than at home. This will fully charge an average pure electric car in three to four hours.
	Rapid charge (up to 43kW AC, up to 50kW DC) Alternative term: <ul style="list-style-type: none"> Quick charge 	Rapid charge will only occur at dedicated charge bays. This will charge the average pure electric car to 80% charge in around 30 minutes. Cars are usually configured for either AC or DC rapid charging, but not both. Many rapid chargers offer both AC and DC rapid charging options.
	Opportunity charge Alternative terms: <ul style="list-style-type: none"> Top up charge Destination charging 	Opportunity charging means the vehicle is charged whenever there is a chance to do so, allowing the battery to be topped up for example, at a supermarket while the vehicle owner does some shopping.
Alternative charging methods	Inductive charging Alternative term: <ul style="list-style-type: none"> Wireless charging 	Inductive charging means energy is transferred via an electromagnetic field from an off-vehicle inductor to an on-vehicle inductor, which then stores the energy in the batteries. There is a small gap between the two inductors, meaning energy is transferred wirelessly. While this charging technology is already available, its rollout and wider implementation is currently being studied and trialled.
	Battery exchange Alternative description: <ul style="list-style-type: none"> Battery swap 	Battery exchange systems allow a depleted battery to be quickly exchanged for a fully charged battery at a battery exchange (or swap) station. Vehicles must be specially designed to accommodate battery exchange technology.



EXECUTIVE SUMMARY

About this Guide

The purpose of this guide is to provide a one-stop guide for the **wider automotive industry and its stakeholders** on general issues related to Ultra Low Emission Vehicles (ULEVs). These include practical information such as the types of ULEVs available, the benefits of ULEVs, charging or refuelling, batteries, safety and running costs.

This document is **not primarily aimed at the end consumer**, for whom information on the Go Ultra Low campaign website⁵ is specifically tailored. Interested end consumers however are welcome to browse this document for wider information.

Given the typical models and types of ULEV currently on UK roads, this document covers only electric vehicles and fuel cell electric vehicles, with a **specific focus on cars**.

ULEV vehicle performance

'Ultra low emission vehicle' (ULEV) is the term used to describe any vehicle that uses low carbon technologies and emits less than 75g of CO₂/km from the tailpipe and is capable of operating in zero tailpipe emission mode for a range of at least ten miles. These range from pure electric vehicles and fuel cell electric vehicles both zero emission at the tailpipe, to plug-in hybrids and extended range electric vehicles. These are also the thresholds for the government's consumer incentive scheme, the Plug-in Car Grant (PiCG).

Most ULEVs on the road today use alternative fuels such as electricity and hydrogen to drive an electric motor. Batteries are commonly used as an energy storage device in most ULEVs. In most instances these batteries are charged by being plugged into a dedicated chargepoint or directly into the mains. An ULEV powered by hydrogen can be refuelled at hydrogen refuelling stations in a way that is similar to refuelling a petrol or diesel vehicle

All **pure electric** cars qualifying for the PiCG must be able to travel at least 70 miles on a single charge and many are capable of 100 miles or more.

Plug-in hybrid cars qualifying for the PiCG must be able to travel in excess of ten miles on battery power, although many are able to travel further, before reverting to normal hybrid operation (utilising both battery power and Internal Combustion Engines).

Extended range electric cars qualifying for the PiCG must meet requirements relating to plug-in hybrids, but are typically able to travel in excess of 100 miles on battery power with hundreds of miles of additional range via the on-board generator.

Fuel cell electric cars are relatively new to the UK market, with the first models only arriving in autumn 2014. The Office for Low Emission Vehicles (OLEV) has indicated that these vehicles will be eligible for the PiCG. As of November 2015, the Toyota Mirai was officially listed as being eligible for the PiCG.

The average individual journey length in the UK is 7.1 miles⁶ and the average total daily distance travelled is 25 miles.⁷ These distances can be comfortably achieved using pure electric cars as well as fuel cell electric cars. Many journeys can be made with plug-in hybrid or extended range electric cars using only battery power.

⁵ www.goultralow.com

⁶ UK National Travel Survey, 2012 data published in 2013.

⁷ UK Office for National Statistics.

Infrastructure and charging

Most ULEVs that have the capability to be plugged in to charge a battery will be charged at home.⁸ The Government's Electric Vehicle Homecharge Scheme provides grants for owners of ULEVs to install chargepoints at home.⁹ However, public charging infrastructure is also available when drivers are away from home. As part of the Plugged-in Places scheme (PiP), the UK government co-funded the roll-out of more than 9,000 chargepoints by March 2013 in London, the North East, Milton Keynes, Scotland, Northern Ireland, Greater Manchester, the Midlands and the East of England. The PiP scheme helped inform plans for a national charging network.

Since 2013, the operation of the scheme in specific regions has gradually transitioned to private operators. Examples include Chargemaster in Milton Keynes and the Midlands, Bluepoint in London, and Charge Your Car in the North East of England, which is rapidly expanding into a national pay-as-you-go recharging network. An increasing number of public/business/retail car parks and new housing developments also offer charging facilities. So much so the UK now has the largest network of rapid chargers in Europe.¹⁰



There is sufficient generating capacity to cope with the uptake of EVs, particularly where charging takes place overnight when there is excess electricity production. Where local energy networks are already close to capacity, localised upgrading of the network may be necessary for a future cluster of vehicles charging during peak hours. Electricity companies are working with EV manufacturers to prepare for the future increase in demand from EVs. This includes the development of smart metering systems which can automatically select charging times and tariffs. This can also help to manage demand on the grid.¹¹

Fuel Cell Electric Vehicles (FCEVs), despite having an electric motor, do not require charging from an external source to run. These vehicles use refuelling stations, which provide an experience similar to refuelling an Internal Combustion Engine (ICE) vehicle. Currently there are three hydrogen refuelling stations (HRS) that offer public access. However, a £5.5million government investment under the Hydrogen for Transport Advancement Programme aims to have 12 HRSs operational by the end of 2016, three of which will be new stations. This represents a significant first step towards an initial network of 65 HRSs by 2020 as recommended by the UKH₂Mobility consortium. The consortium has set out a roadmap towards achieving full national coverage with 1,150 stations by 2030.¹²

On the road cost and incentives

ULEVs have a very low running cost, which means the total cost of ownership can be attractive. Additionally, the purchase price is falling as ULEVs are becoming more common. The PiCG offers a specific amount off the purchase price of qualifying ULEVs.

To be eligible for the PiCG, vehicles must meet specific requirements, including the following:

⁸ It is recommended to install a home charging unit on a dedicated EV circuit. This will ensure the circuit can manage the electricity demand from the vehicle and that the circuit is activated only when the charger communicates with the vehicle, known as the 'handshake'. If you are charging outdoors, an external weatherproof socket can also be installed.

⁹ <https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-guidance-for-customers-2015>

¹⁰ OLEV, <http://www.chademo.com/wp/wp-content/uploads/2014/10/OLEV.pdf>

¹¹ BERR and DfT, Investigation into the scope for the transport sector to switch to electric vehicles and plug-in hybrids, 2008.

¹² UKH₂Mobility, Phase 1 Results, April 2013.

- Only new vehicles of category M1 (passenger cars).
- Vehicles must emit less than 75g CO₂/km.
- Battery Electric Vehicles (BEVs) must be able to travel a minimum of 70 miles between charges. Plug-in Hybrid Electric Vehicles (PHEVs) must have a minimum electric range of ten miles.
- Vehicles must be able to reach a top speed of 60 miles/hour.
- Vehicles must have a three year or 60,000 vehicle warranty and a three year battery and electric drive train warranty, with the option of extending the battery warranty for an extra two years.
- Vehicles must have either a minimum five year warranty on the battery and electric drive train as standard or extra evidence of battery performance to show reasonable performance after three years of use.
- Vehicles must comply with regulations (UN-ECE Reg 100.00) that demonstrate they are electrically safe.
- To ensure they are safe in a crash, vehicles must either have a European Commission Whole Vehicle Type-Approval (EC WVTA, not small series) or evidence that the car has appropriate levels of safety as judged by international standards.

In April 2015, the government introduced three grant categories for cars under the PiCG. These categories were designed to differentiate between ULEVs on the basis of their CO₂ emissions and their zero emission range. The categories are:



From 1 March 2016, although the above categories remained unchanged, the following new rates now apply:

- £4,500 for eligible Category 1 vehicles
- £2,500 for eligible Category 2 vehicles
- £2,500 for eligible Category 3 vehicles

The grant will be maintained at these levels until March 2018, or until a prescribed number of each type of vehicle have been sold, or whichever is sooner.

The trigger points for a further review of grant levels will be 40,000 Category 1 vehicles, and 45,000 combined sales of Category 2 and 3 vehicles, with both totals including cars sold before March 2016. As of December 2015 23,000 claims had been submitted for Category 1 vehicles and 28,000 claims for Category 2 and 3 vehicles.

To encourage zero emission vehicles and maximise the number of everyday motorists who can benefit, a price cap for Category 2 and 3 vehicles will operate from 1 March 2016. **Vehicles that cost £60,000 and above will no longer be eligible for the grant.** There will be a derogation for Category 1 vehicles, which will remain eligible for the full grant.

Many tax incentives apply to ULEVs, such as currently paying no VED (road tax) and, in some areas, benefit from 100% congestion charge discount and free parking. Changes to VED for new cars registered from 1 April 2017 mean that only zero emission vehicles will be VED exempt, although other

ULEVs will still benefit from a reduced first year VED rate.¹³ The typical cost of electricity to charge an EV is approximately £0.02 per mile,¹⁴ compared to fuel costs of £0.12 per mile for an ICE.¹⁵

Emissions

The current lowest emitting ICE produces tailpipe emissions of 79g CO₂/km.¹⁶ ULEVs have zero emission at the tailpipe, or also referred to as 'tank-to-wheel', when powered solely by battery or hydrogen through fuel cell stacks. A 'well-to-wheel' analysis includes the CO₂ emissions during electricity generation, which depends on the current mixture of fuels used to produce the electricity for the grid, or during hydrogen production. To make a more accurate comparison of emissions from all cars, the 'well-to-wheel' figure is most objective, as it includes CO₂ emissions during production, refining and distribution of petrol/diesel. However, well-to-wheel calculations are complex and depend on a range of variables, for which there is yet to be any industry consensus. As such there are currently no definitive well-to-wheel figures.

As electricity production decarbonises through an increase in renewable energy generation, the overall emission figure for running an EV will drop further.

It is worth noting that the standard industry metrics only consider CO₂ emissions. However, tailpipe emissions include oxides of nitrogen (NOx) and particulate matter (tiny particles of solid or liquid matter) which contribute to air pollution. This is why vehicle manufacturers are striving to reduce tailpipe emissions and why any vehicle operating solely on battery or fuel cell power can play a significant role in improving local air quality.

FCEVs also benefit from having zero emissions. Hydrogen is non-toxic, clean and a safe energy source. Most of the hydrogen produced globally comes from natural gas, but even when using methane-derived hydrogen, FCEVs offer 'well-to-wheel' CO₂ emissions comparable to the most efficient petrol/diesel and, most importantly, produce no harmful emissions locally.



Safety

ULEVs are tested to the same high safety standards as other vehicles currently on UK roads. The first pure electric car was assessed and passed the Euro NCAP test as far back as February 2011.

While the quietness of ULEVs is a benefit for drivers and passengers, concerns have been raised that it can pose a threat to sight and hearing-impaired people at low speeds. Research has found that tyre noise will alert pedestrians to a vehicle's presence at speeds above 12mph.¹⁷

As FCEVs use energy-dense hydrogen, there is potential danger to health and property in the event of uncontrolled combustion or explosion. However, this is similar to, and a common safety risk with petrol and natural gas.¹⁸ Furthermore, European Whole Vehicle Type Approval requirements include detailed requirements on the design and testing of hydrogen fuel systems to ensure their safety.

¹³ <https://www.gov.uk/government/publications/vehicle-excise-duty>

¹⁴ Based on a 24kWh battery delivering 100 miles. Calculated using an average of standard and low rate electricity. www.goultralow.com also have further information on this.

¹⁵ Based on current petrol prices (AA)

¹⁶ SMMT New Car CO₂ Report 2016

¹⁷ Green Car Reports (www.greencarreports.com)

¹⁸ HyFive: <http://www.hyfive.eu/hydrogen-and-fuel-cells/>

CHAPTER 1

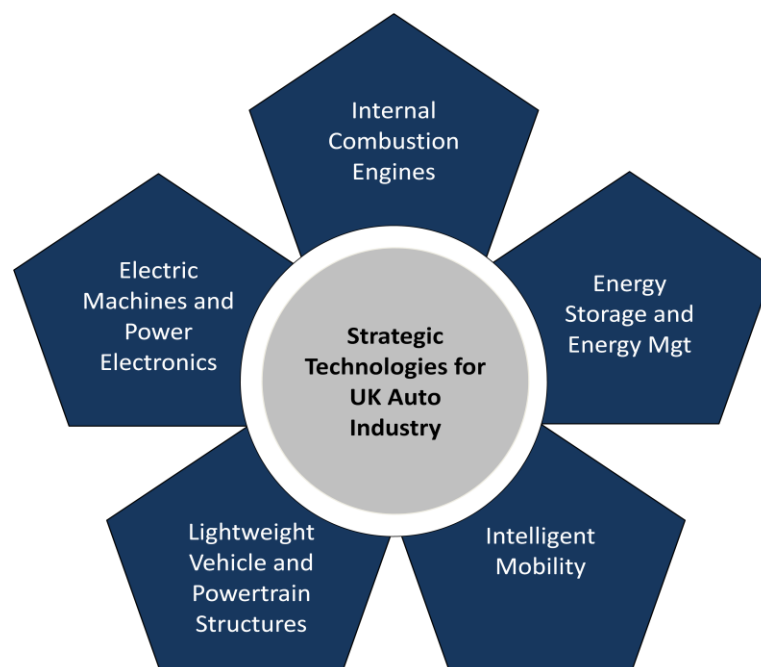
INTRODUCTION: ULTRA LOW EMISSION VEHICLES

The term 'ultra low emission vehicle' (ULEV) refers to any vehicle that uses low carbon technologies and emits less than 75g of CO₂/km at the tailpipe and is capable of operating in zero tailpipe emission mode for a range of at least ten miles.

Most ULEVs on the road today use alternative fuels such as electricity and hydrogen to drive an electric motor. Batteries are commonly used as the main energy storage device in most ULEVs. In most instances these batteries are charged by being plugged into a dedicated chargepoint or directly into the mains. An ULEV powered by hydrogen can be refuelled at hydrogen refuelling stations in a way that is similar to refuelling a petrol or diesel vehicle. The emission threshold for the government's consumer incentive scheme, the Plug-in Car Grant (PiCG), is also currently at 75g of CO₂/km, but with an additional criterion of a minimum of ten miles of zero emission driving.

The Automotive Council, established in 2009 to enhance dialogue and strengthen cooperation between government and the automotive industry, had originally identified five strategic technologies that have the potential to shape the future of the UK automotive industry. Four of these five 'sticky technologies' (with the exception of intelligent mobility) have direct impact on the automotive industry's ambition to achieve and exceed emission targets set by the EU.

The Automotive Council's five strategic technologies for the UK automotive industry



Building on the five strategic technologies, the Automotive Council's Technology Group currently has work streams operating on the following priority R&D areas, all with direct or indirect impact on the development of low emission technologies:

- **Future Technology**

To conduct analysis of the future technology needs for the sector to improve coordination and collaboration with the academic research community, establish an advisory group to help align research funding with industry challenges where relevant.

- **Technology R&D**

To consider opportunities from European Union research and development funding and how to improve collaboration to better access it.

- **Manufacturing Technology**

To identify the future high value manufacturing technologies that are required to deliver the technology roadmaps published here.

- **Intelligent Mobility**

With Intelligent Mobility cutting across and going beyond the traditional transport sector this work stream is developing a strategy for the UK which utilises the emerging technological markets to enable user-focused, integrated, efficient and sustainable transport systems.

- **Energy storage and energy management**

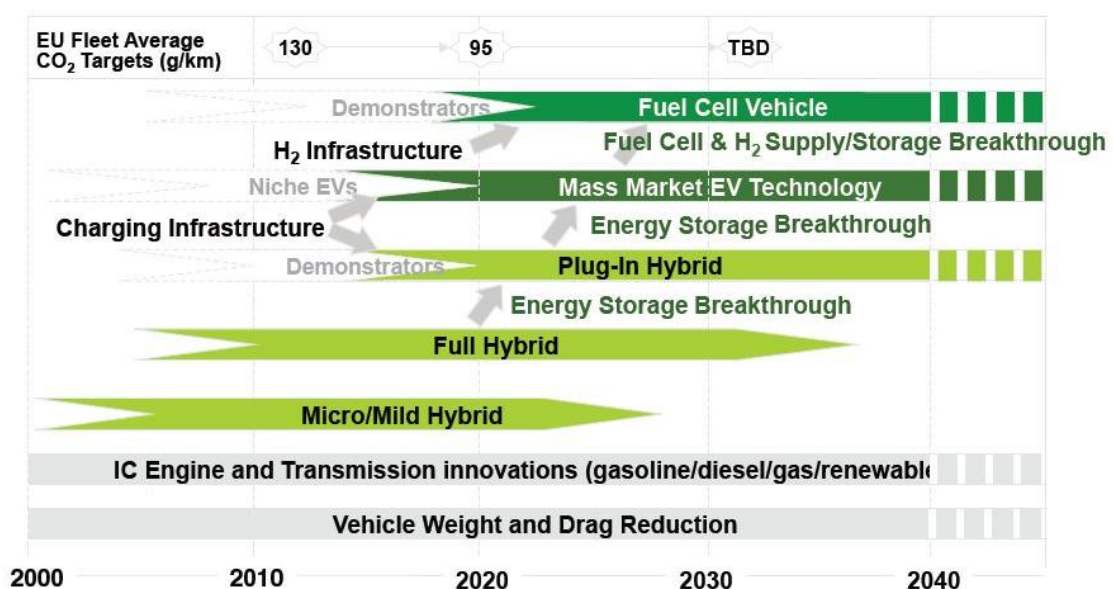
To create a non-electrochemical energy storage road map describing energy devices, the means of transferring energy and the potential impact on overall vehicle architecture.

- **Design**

The Design work stream was established in January 2014 with the objective of maintaining and building UK strength in the discipline.

The Automotive Council has also published a series of roadmaps that illustrate the advances that will be made in automotive technology in the coming decades. The passenger car low carbon technology roadmap sets out a variety of technologies that will help reduce tailpipe emissions and fulfil the promise of greener motoring. Many of these technologies are already available in today's ULEVs. These include pure electric, plug-in hybrid, extended range electric and fuel cell electric propulsion.

The Automotive Council Technology Group's passenger car low carbon technology roadmap



Aims and Focus

The purpose of this document is to provide a one-stop guide for the **wider automotive industry and its stakeholders** on general issues related to ULEVs. It includes practical information such as the types of ULEVs currently available, the benefits of ULEVs, charging or refuelling, batteries, safety and running costs.

This document is **not primarily aimed at the end consumer**, for whom information on the Go Ultra Low campaign website is specifically tailored. Interested end consumers however are welcome to browse this document for wider information.

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For further information, please contact the SMMT Technology and Innovation team at evgweb@smmt.co.uk.

CHAPTER 2

OPERATIONAL

Vehicle experience, range, speed and suitability

2.1 What Ultra Low Emission Vehicles (ULEVs) are available?

ULEVs encompass the following technologies:¹⁹

- Battery Electric Vehicles (BEVs)
- Plug-in Hybrid Electric Vehicles (PHEVs)
- Extended-Range Electric Vehicles (E-REVs)
- Fuel Cell Electric Vehicles (FCEVs)

Battery Electric Vehicles (BEVs) – wholly electric vehicles powered by a battery. Currently most manufacturers offer pure electric cars with a range up to 100 miles or more.



Plug-in Hybrid Electric Vehicles (PHEVs) – battery range in excess of ten miles. After the battery range is utilised, the vehicle reverts to conventional hybrid operation (utilising both battery power and ICE).



¹⁹ NB: This document does not include quadricycles, motorcycles or bicycles when referring to EVs.

Extended-Range Electric Vehicles (E-REVs) – similar to BEVs but typically with a shorter pure electric range of around 40 miles-100 miles, range is extended by an ICE on-board generator providing many additional miles of mobility. With an E-REV, the propulsion technology is always electric, unlike a PHEV where the propulsion technology can be electric or hybrid.



Fuel Cell Electric Vehicles (FCEVs) – using hydrogen fuel cell technology, these vehicles have a range typically of 300 miles or more. Hydrogen fuel cells help drive an electric motor, and emit only water vapour, making it zero emission like a BEV.



2.2 What are the benefits of ULEVs?

Electricity is one of the key options with great potential as an alternative to petrol/diesel. It can be produced from sustainable sources, it can be readily supplied and it produces no emissions at the point of use. This means ULEVs that are powered through electricity can offer significant environmental benefits when used as urban commuter transport. Here are some of the benefits of EVs when operating solely on battery power:

- no emissions at the point of use
- low well-to-wheel emissions
- a quiet driving experience
- fun to drive
- easy to use infrastructure – most charging is carried out at home
- practical and easy to drive, particularly in urban stop-start traffic
- home charging is convenient and avoids queuing at petrol stations

FCEVs also offer a great alternative to petrol/diesel, for many of the same reasons as ULEVs powered by electricity; because these vehicles emit only water vapour they help provide environmental benefits to

urban communities and to society as a whole. FCEVs also provide driving range that is comparable to ICE vehicles and fast refuelling.

2.3 What are ULEVs like to drive?

ULEVs are easy and fun to drive. Smooth, swift acceleration and light handling make the driving experience very enjoyable. Many of these vehicles are responsive, quick and have a smooth acceleration.²⁰ Electric motors are very quiet, which means the driver is in a quiet, calm environment. Similar to automatic cars, there is no gearbox, which is particularly useful in built-up areas or heavy traffic. ULEVs require the same driving licence as traditional cars (category 'B') and pure electric cars can be driven on an automatic-only driving licence.

2.4 What is the top speed and acceleration of an ULEV?

ULEVs specifications indicate that they are able to achieve similar speeds to their ICE counterparts in everyday driving. All ULEVs which qualify for the government's PiCG must be capable of reaching speeds of 60mph or more. Some pure electric cars can reach speeds up to 155mph where permitted.²¹

Power is delivered by the electric motor as soon as the vehicle begins to move, which gives smooth and swift acceleration. For more information on speed and vehicle performance, visit the manufacturers' websites.

2.5 Does an ULEV have adequate range for all motoring needs?

Range depends on the type of ULEV and how it is driven. Currently, some PHEVs have a range of up to 700 miles, however most pure electric cars offer a range up to 100 miles and are ideal for short to medium length journeys. Compared to manufacturers' published range based on test cycles, actual driven range may vary, just like ICE vehicles, depending on several factors, such as driving behaviour and the use of heating and lights. An E-REV, PHEV or FCEV may be more suitable for regular medium range journeys or those over 100 miles.

The average individual journey length in the UK is 7.1 miles²² and the average total daily distance travelled is 25 miles.²³ In fact 36% of people in the UK never travel further than 80 miles,²⁴ and in Europe, more than 80% of Europeans drive less than 63 miles on a typical day. A significant number of journeys can therefore easily be made using an ULEV, and more specifically a pure electric car.

2.6 Will ULEVs suit everyone?

Not all vehicles in the market are suitable for all drivers but there is a ULEV to match the transport needs of a great proportion of the population.

The intended use will determine what type of ULEV is most suitable. Manufacturers are introducing more car models, which will satisfy the demand for vehicles of different size and capacity. There are now cars in the super luxury market as well as multi-purpose vehicles (SUVs), city run-arounds and family hatchbacks.

Charging and refuelling

2.7 Where can users charge/refuel ULEVs?

EVs can be charged at home, at some workplaces, on-street and in a number of public places such as car parks and supermarkets.

²⁰ <https://www.goultralow.com/what-are-go-ultra-low-cars/>

²¹ Tesla: http://www.teslamotors.com/en_GB/

²² UK National Travel Survey, 2013

²³ UK Office for National Statistics.

²⁴ See statistics in www.goultralow.com

UK and overseas trials suggest most EVs will be charged at home. Home charging can be done by installing dedicated weatherproof sockets outside or in a garage. A dedicated EV circuit is recommended for the chargepoint, similar to those required for other high power appliances such as power showers and electric cookers.²⁵ It is advisable that customers ensure that their chargepoint and wiring have been approved by a qualified electrician before they commence home charging. A timer either in the car's system or on a mobile app can control charging to occur only at night to take advantage of off-peak electricity rates. The Government's Electric Vehicle Homecharge Scheme provides grants for owners of ULEVs to install chargepoints at their homes.²⁶

Public charging networks offer a mix of slow, fast and rapid chargepoints operated by either a national or regional network. The largest regional networks include: Source London, ChargePoint Scotland, Plugged-in Midlands and Northern Ireland. Once a member, EV users have access to all chargepoints in networks with which they are registered. For those without access to off-street parking at home, charging infrastructure is available in public locations and may also be available at work. Further information about charging infrastructure can be obtained from local authorities. Information on national infrastructure can be found at www.zapmap.com and www.goultralow.com.



Future charging technologies are continuously being explored. These include inductive charging, where vehicles will be fitted with wireless technology and a charging plate installed underneath the road or tarmac surface, thus enabling charging to take place wirelessly. The government had explored the potential of Dynamic Wireless Power Transfer (DWPT), which will allow vehicles to charge while on the move. It was envisaged that this technology would help create a more sustainable road network, as well as provide more opportunities for low carbon mobility of people and goods across the UK. However, these plans have been shelved pending further review.²⁷

FCEVs do not require chargepoints but use Hydrogen Refuelling Stations. Currently there are three hydrogen refuelling stations (HRS) that offer public access. However, a £5.5million government investment under the Hydrogen for Transport Advancement Programme aims to have 12 publicly accessible HRSs operational by the end of 2016. This represents a significant first step towards an initial network of 65 HRSs by 2020 as recommended by the UKH₂Mobility consortium. The consortium has set out a roadmap towards achieving full national coverage with 1,150 stations by 2030.²⁸ However, when compared to a pure EV on a range basis, assuming all other factors equal, a FCEV does not need to refuel as frequently as a pure EV needs recharging.

²⁵ Separate circuits are installed for units which draw a large amount of electricity to prevent overload on the household supply.

²⁶ <https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-guidance-for-customers-2015>

²⁷ <https://www.gov.uk/government/news/off-road-trials-for-electric-highways-technology>

²⁸ UKH₂Mobility, Phase 1 Results, April 2013.

The UKH₂Mobility's projection of FCEV uptake and number of hydrogen refuelling stations

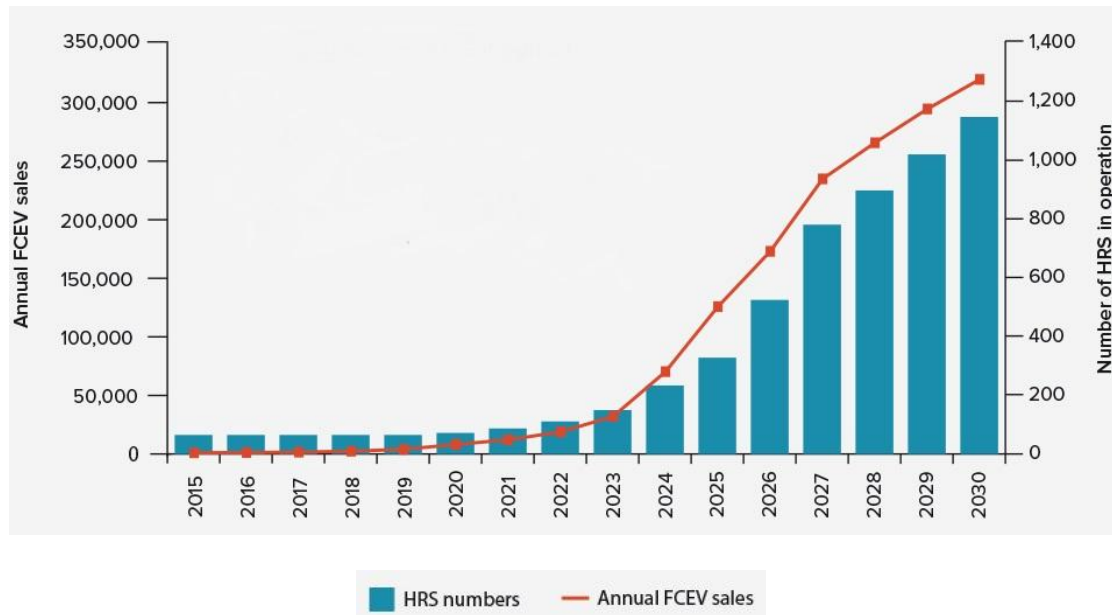


Chart courtesy of UKH₂Mobility

Envisaged network of hydrogen refuelling stations

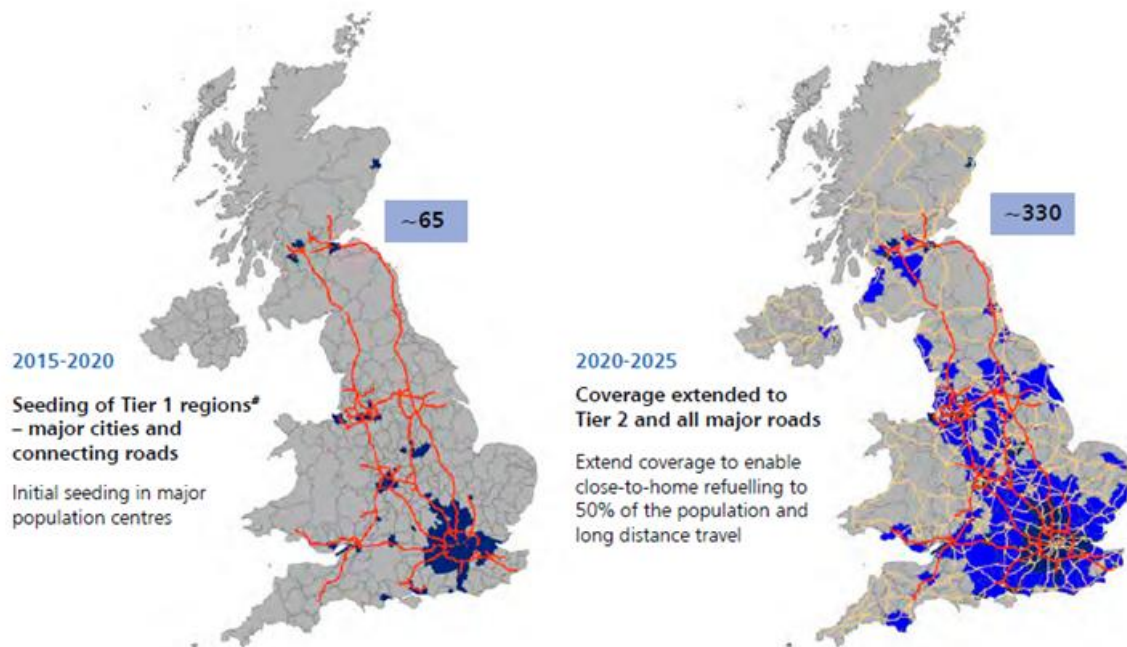


Figure courtesy of BOC.²⁹

²⁹ http://www.boconline.co.uk/internet.lg.lg.gbr/en/images/UK-H2Mobility-Report-Phase-1-Results410_91685.pdf

2.8 How many public chargepoints are there in the UK and what is being done to increase this number?

There are currently more than 9,000 public chargepoints already rolled out across the UK, with more appearing.³⁰ These chargepoints were made possible by government providing seed funding of up to £30 million under the Plugged-in Places (PiP) scheme to ensure public charging infrastructure is available in a number of UK locations. These have included London, Milton Keynes, the Midlands, Greater Manchester, East of England, the North East, Scotland and Northern Ireland. As mentioned, PiP schemes have since gradually transitioned to private operators. Most of these networks offer a mix of slow, fast and rapid charging options. To see the available public charging networks in each region, visit Zap-Map: www.zap-map.com/charge-points/public-charging-point-networks/

Chargepoint in numbers, as at 3 February 2016³¹



UK chargepoints by charger speed, February 2016

PROFILE OF UK CHARGING CONNECTORS BY CHARGER SPEED: ZAP-MAP, FEBRUARY 2016

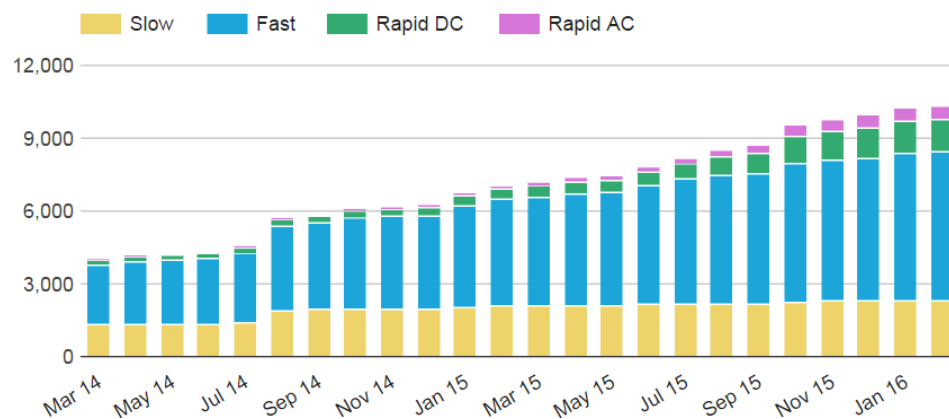


Chart courtesy of Zap-Map

2.9 How much does it cost to charge/refuel an ULEV?

The cost of charging an EV depends on the size of the battery and how much charge is left in the battery before charging. As a guide, charging an electric car with a range of around 100 miles from flat to full will cost from as little as £3 depending on the tariff the household is currently on.³² This means the average cost of 'fuel' will be approximately £0.03 per mile. Another calculation puts the figure at £0.02

³⁰ <https://www.zap-map.com/>

³¹ Statistics by Zap-Map. See <https://www.zap-map.com/statistics/>

³² Energy Saving Trust <http://www.energysavingtrust.org.uk/domestic/electric-vehicles-0>

per mile.³³ In comparison driving 100 miles in an ICE would cost around £12-£18 in fuel, equating to roughly six times the cost of the electric cars.³⁴

Charging overnight may allow EV owners to take advantage of the cheapest electricity rates when there is surplus energy. The cost of charging from public infrastructure will vary; some still offer free electricity in the short term.

FCEVs refuel at hydrogen refuelling stations (HRSs). Refuelling is a similar process to putting petrol/diesel in an ICE vehicle and takes approximately three to five minutes. Hydrogen in the UK can be supplied to vehicles at either 350 bar or 700 bar. Hydrogen has an estimated pump price of £10 per kg. The hydrogen storage capacity of FCEVs refuelled at 700 bar is around 5kg.³⁵

2.10 How do EV owners pay for charging?

For home charging the cost of electricity used will be reflected in the electricity bill.

At present, different schemes have different arrangements for paying for public charging. Chargepoints may belong to different networks, with many of these running an access card scheme, a membership scheme, a pay-as-you-go system, or a combination of these. Some national charging networks still offer free use of their chargepoints.³⁶

2.11 How long does it take to charge an EV?

How long it takes to charge an EV depends on the type of vehicle, how depleted the battery is and the type of chargepoint used.

Under the PiP scheme, different charging technologies, including standard/slow (up to 3kW),³⁷ fast (7-22kW) and rapid charging facilities (up to 43kW AC, up to 50kW DC), were installed in different localities. Further information on national infrastructure can be found at www.zapmap.com and www.goultralow.com

Typically, BEVs using standard charging will take between six and eight hours to charge fully using a standard chargepoint and can be 'opportunity charged' to keep the battery topped up.

BEVs capable of using rapid chargepoints can be 80% charged in around 30 minutes, and could take roughly an hour to reach 100% capacity. BEVs can be 'topped up' in around 20 minutes, depending on the type of chargepoint and available power. PHEVs take approximately one and a half hours to charge from a standard chargepoint. E-REVs will have the same charge time as a PHEV. PHEVs and E-REVs generally require less time to charge as their batteries tend to be smaller than those of BEVs.

2.12 What if a chargepoint is already occupied?

Some chargepoints will be bookable online, so EV drivers can plan their journey and charging. A number of mobile applications are available to show users where there are available chargepoints across a city or region. Charging network operators also provide assistance and information to EV drivers looking for chargepoints. Some publicly accessible chargepoints display the time elapsed and energy supplied.

2.13 What happens if a battery electric car runs out of charge?

Manufacturers take every precaution to ensure the vehicle informs the driver of the available charge remaining in the battery. As with ICEs, a 'fuel' gauge will indicate how much charge is left in the battery.

³³ Based on a 24kWh battery delivering 100 miles. Calculated using an average of standard and low rate electricity. www.goultralow.com also have further information on this.

³⁴ Ibid

³⁵ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/192440/13-799-uk-h2-mobility-phase-1-results.pdf

³⁶ <https://www.zap-map.com/charge-points/public-charging-point-networks/>

³⁷ This is for use with standard 13A domestic electricity supply.

If the driver continues without recharging the consequence will be similar to running out of fuel and breakdown assistance organisations can assist motorists to reach their destinations and charge their battery; an EV running out of charge can be recovered to a public chargepoint. If the vehicle is DC-capable it can be mobile again in a matter of minutes.

2.14 Do all EVs and chargepoints have a standard plug and socket? Will UK-registered EVs charge in other countries?

Global standards exist for a range of different EV-specific plugs and sockets. It is advisable to check with the vehicle manufacturer regarding charging equipment such as the cable which may be provided with the vehicle. Many manufacturers have made it possible for EV users to take their vehicles into the EU with provisions to be compatible with European EV chargepoints.

The Institute of Engineering and Technology (IET) Code of Practice for Electric Vehicle Charging Equipment Installation Second Edition provides information about the three charging connectors currently in use. These include a Yazaki connector and a Mennekes (Type 2). Other socket outlets for AC use are permitted by the fixed wiring standards but this limits interoperability for those without this socket. The Code of Practice also outlines the regulations for socket-outlets, connectors and cables (Regulation 722.55.101).

Most EVs will connect with most chargepoints, but at times users may need additional connectors. EVs usually come with a cable that uses a conventional three pin plug to connect to a chargepoint. This type of plug makes it easy to connect to a normal three pin domestic socket; using a three pin domestic socket, however, should be a last resort.



For rapid charging, there are three main industry standards: CHAdeMo, 43kW AC charger and the Combi charging system. The CHAdeMO chargepoint network is currently the most developed in the UK, but there are over 550 rapid chargepoints across the UK that support all three standards, providing drivers with greater choice and ease of mind when it comes to charging their vehicles.³⁸

Main connector types for electric vehicle charging

3-Pin	Commando	Type 1	Type 2
			
Slow (AC)	Slow or Fast (AC)	Slow (AC)	Slow, Fast, Rapid (AC)

³⁸ www.goultralow.com



Images courtesy of Next Green Car³⁹

There are a number of different charging modes, but in simple terms there are two distinct types: alternating current (AC) or direct current (DC). The battery pack within an EV is always charged by DC. Power provided by electricity companies is delivered in the form of AC and therefore it needs to be converted to DC, either by a DC rapid chargepoint or by the on-board charger within the vehicle, before it reaches the vehicle battery pack. The power of the on-board charger is limited by the space and weight considerations for the vehicle.

In the case of DC rapid charging, the AC provided by the electricity network is converted to DC within the chargepoint itself and therefore the DC bypasses the on board charger in the vehicle. As a rule of thumb, slow and fast chargepoints are currently invariably AC, whereas rapid chargepoints may be either AC or DC.

2.15 Can anyone unplug an EV when it is charging?

For those charging at home this is unlikely to occur. Public chargepoints are locked when vehicles are charging, meaning passers-by cannot unplug the cable. Some chargepoints can send a text message to the car owner in the unlikely event there is an error or tell the owner when the vehicle is fully charged. If the charge cable was removed, charging would cease until the charger was re-set by the authorised user.

2.16 Is it safe to charge in wet weather?

Yes, it is safe to charge in wet weather. Weatherproof charging equipment can be installed. When installing a charging facility at home, the supplier will be able to provide further advice about charging safely.



2.17 Will special equipment need to be installed to charge an EV at home?

It is strongly recommended that EV owners ensure their home charging socket and wiring have been installed and approved by a qualified electrician before they commence charging. A home chargepoint with its own dedicated circuit is a sensible means of charging an EV safely and economically.⁴⁰ This will ensure the circuit can manage the electricity demand from the vehicle and that the circuit is activated only when the charger communicates with the vehicle, known as the 'handshake'. It may also be programmable, enabling the EV owner to benefit from off-peak electricity tariffs without having to remember to switch on the circuit late at night.

For outdoor charging, a number of EV manufacturers offer home chargepoints in association with energy companies that are fully weatherproof and safe to charge outside.

³⁹ <http://www.nextgreencar.com/electric-cars/charging-points.php>

⁴⁰ Separate circuits are installed for units which draw a large amount of electricity to prevent overload on the household supply.

For rapid charging, special equipment and an upgraded electrical supply would be required and is therefore unlikely to be installed at home.

The IET Code of Practice for Electric Vehicle Charging Equipment Installation provides an overview of electric vehicle charging equipment, has guidance on electrical installation requirements, and also includes a useful installation checklist.⁴¹

2.18 Where can flat dwellers with no dedicated parking charge an EV?

EV owners without access to dedicated parking will need to establish what sort of public charging infrastructure is available in their area. This can be done by contacting the local authority or by searching on Zap-Map. OLEV also has an on-street residential chargepoint scheme.⁴²

2.19 Will there be wires trailing across the pavement?

Charging EVs using public infrastructure should not involve trailing wires if the vehicle is parked close to the chargepoint. It is not recommended that people without an off-street parking facility (e.g. garage or driveway) charge at home.

2.20 How can an EV be charged from low carbon energy?

All electricity has an element of renewable electricity in it as a result of the 'Renewable Obligations' placed on electricity suppliers.

If charging from home supply, EV owners may request a green electricity tariff from their supplier. By signing up to a green electricity tariff, the electricity supplier has to provide evidence to demonstrate that its tariff results in a reduction of a minimum threshold of CO₂ emissions.

Electricity suppliers must show that the activity associated with the green tariff is in addition to what they already have to do to meet existing government targets for sourcing more renewable electricity and reducing household carbon emissions.

It is worth knowing that not all green tariffs provide 100% additional renewable electricity. The Energy Saving Trust gives advice on buying green electricity. See www.energysavingtrust.org.uk/domestic/buying-green-electricity

Batteries

2.21 How long will the battery last in an EV?

Battery manufacturers usually consider the end of life for a battery to be when its capacity drops to 80% of its rated capacity. This means that if the original battery has a range of 100 miles on a full charge, after eight to ten years (depending on how much the vehicle has been driven) this may have reduced to 80 miles. However, batteries can still deliver usable power below 80% charge capacity, although this will produce shorter range.

2.22 Does using the radio, lights and air-conditioning/heating reduce range?

Yes, this will impact on the range to some extent, particularly in pure EVs. As with conventional ICE vehicles, running air-conditioning excessively will affect fuel consumption, as will carrying a heavy load or driving against severe resistance such as headwinds. Many vehicle manufacturers are using innovative solutions such as LED exterior lights to reduce energy consumption while control systems

⁴¹ <http://www.theiet.org/resources/standards/ev-cop.cfm>

⁴² https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226841/onstreet-rapid-chargepoints-local-authority.pdf

can be used in EVs to minimise the amount of energy used by additional items such as air-conditioning and heating.

2.23 What is the cost of a replacement battery?

That depends on the size and type of the battery, which are determined partly by the vehicle. Batteries are relatively expensive at the moment but it is likely that prices will decrease as technology improves and volumes increase. Customers are advised to speak to manufacturers for more information.

2.24 Will the price of copper, lithium or rare earth metals have an effect on the cost of an ULEV?

Despite fluctuations in the market price of raw materials in recent years, there has not been a corresponding impact on the cost of these materials (specifically copper) to ULEV battery manufacturers. The same applies to lithium, although securing sufficient levels of supply could cause temporary price increases if there is a huge and sudden increase in battery production. Economies of scale of high voltage battery production will also contribute towards the reduction of cost for high volume batteries. Rare earth materials are used in some, but not all types of EV electric motors. Lithium and rare earth material costs contribute only a small proportion of the cost of an electric powertrain, so material costs have only a very small impact on overall vehicles cost.

2.25 Is a breakthrough in battery technology imminent?

Using existing battery technology, ULEVs are already capable of meeting the needs of the majority of daily journeys.⁴³ Nevertheless, battery technology continues to improve, thus promising an increase in range and power and a decrease in cost, weight and size in the future. Step-change technologies such as lithium-air and solid-state batteries have already been touted as potential game changers in electromobility of the future. In the meantime, batteries are getting larger, which enables an increase in range, and vehicles are being built using light weight materials and components to offset the battery weight.

Servicing, repair and breakdown

2.26 Where can an ULEV be repaired or serviced?

Manufacturers will ensure that service technicians are provided with detailed service instructions and training, just as they do for ICE vehicles. In addition, industry training programmes are being developed to ensure dealers, technicians, manufacturing staff, emergency services and breakdown assistance staff can become qualified to handle ULEVs.⁴⁴ Motor Codes, the government-backed self-regulatory body for the motor industry, lists all registered ULEV service and repair centres on its search engine at www.motorcodes.co.uk.

2.27 Do ULEVs require an MOT?

Yes. Just like any ICE vehicle, after three years ULEVs will require annual MOT tests, in line with current legislation.

2.28 What will it cost to service a pure EV or FCEV?

There are fewer moving parts in a pure EV or FCEV, which should reduce servicing costs and



⁴³ The average individual journey length in the UK is 7.1 miles and the average total daily distance travelled is 25 miles. See UK National Travel Survey, 2013, and UK Office for National Statistics.

⁴⁴ The Society of Motor Manufacturers and Traders (SMMT) is working with the Institute of the Motor Industry (IMI) and vehicle manufacturers to introduce dedicated EV training. Contact SMMT for more information.

downtime. When a pure EV or FCEV requires servicing, it will be similar to an ICE service. Although the powertrain is different, many of the service actions for BEVs/FCEVs are similar to ICEs.

The Go Ultra Low campaign's research reveals the average cost of servicing and maintenance bills on a pure electric vehicle is just £94 per a year.⁴⁵

2.29 What warranty can be expected?

The warranty of an ULEV will be in line with current warranties on ICE vehicles. All manufacturers that use the PiCG must offer a minimum three-year battery warranty on the car as standard, as well as an option for the consumer to purchase a further two-year warranty extension.

Recently there have been announcements that certain companies are providing extended warranties to ULEVs.⁴⁶ Most high voltage batteries have an eight year-warranty, which includes the drive train on some vehicles. It should be noted that the mileage will differ for each vehicle covered by these warranties.

2.30 Can ULEVs be towed like regular cars?

In most cases, yes. The manufacturers' emergency response guides provide advice on appropriate recovery methods for the vehicle. If towing is permitted, the restrictions that apply are similar to those for automatic vehicles (e.g. driven wheels must be lifted from the ground, limited speed and/or distance for towing).

2.31 Are the breakdown assistance organisations and emergency services trained to deal with ULEVs?

The industry training programme for ULEV-specific qualifications is being rolled out to dealers, technicians, manufacturing staff, emergency services and breakdown services.⁴⁷ Vehicle manufacturers provide emergency response guides to advise first responders on how to identify an ULEV, the location of its major components and the procedures for performing emergency operations on a disabled vehicle, including rescue of occupants and recovery of the vehicle.

2.32 Do ULEVs work in cold weather?

Manufacturers have carried out extensive testing in extreme weather conditions. In February 2010 everyday users drove their EVs in the worst winter weather conditions in the UK for 30 years.

However, ULEVs' range may be affected by cold weather. The use of heating and other items is likely to increase the load on the battery and reduce the range. Latest FCEVs are tested in extreme conditions and designed to operate at even -30°C, temperatures that are lower than normal ICE operation. This, however, is unlikely to happen in the UK given the average winter temperatures experienced over the past 50 years.

Control systems can be used in ULEVs to minimise the amount of energy used by additional items such as air-conditioning and heating. It is also worth noting that ULEVs do not need a warm-up period like many conventional ICE vehicles do in the winter.

⁴⁵ <https://www.goultralow.com/switch-to-a-new-electric-vehicle-and-save-hundreds-on-your-garage-bills/>

⁴⁶ <http://www.telegraph.co.uk/cars/news/first-extended-warranty-for-electric-cars-introduced/>

⁴⁷ SMMT is working with the Institute of the Motor Industry (IMI) and vehicle manufacturers to introduce dedicated EV training. Contact SMMT for more information.

CHAPTER 3

FINANCIAL

General costs

3.1 How much does it cost to own an ULEV?

The table on the following page sets out illustrative running costs for ULEVs over three years and demonstrates how the additional purchase cost can be offset when EV owners consider the total cost of ownership. To offer a fair assessment, these figures compare an ICE such as a fuel-efficient medium-sized petrol car (136g CO₂/km), to ULEVs of a similar size.

Additional savings in the form of Company Car Tax may accrue to ULEVs registered as company cars. To calculate Company Car Tax and compute running costs for comparison between ULEVs and conventional petrol/diesel cars, please see these calculator tools: [/www.nextgreencar.com/company-car-tax/calculator.php](http://www.nextgreencar.com/company-car-tax/calculator.php) or www.fleetnews.co.uk/cars/car-tax-calculator/

3.2 How much does it cost to charge/refuel an ULEV?

The cost of charging depends on the size of the battery, how depleted the battery is and how quickly it is charged. As a guide, charging a pure electric car battery from flat to full will cost from as little as £3, although there are opportunities for cheaper charging depending on the tariff being used. This is for a typical pure EV with a 24kWh battery offering a range of approximately 100 miles. This means the average cost of 'fuel' will be approximately £0.03 per mile. Similar costs will apply to PHEVs and E-REVs, although as the battery is smaller in these vehicles the cost of charging is likely to be less. Charging overnight may enable EV owners to take advantage of lower electricity rates.



While a report suggests fuel cost targets for FCEVs are €9.90/kg (£7.92/kg) in 2015 and €5.50/kg (£4.40/kg) in 2025,⁴⁸ some FCEVs are being supplied with fuel included as part of the package. In the UK, the current cost of hydrogen is approximately £10/kg, while the target is to get the cost down to between £5-£7/kg. The consensus within the UKH₂Mobility consortium was that hydrogen was likely to be supplied at a cost around 10% lower than diesel on a per kilometre basis.

3.3 Is there an economic case to run an ULEV?

As illustrated on the following pages, the total cost of ownership of an ULEV is similar to or lower than a comparable ICE. If the car is being used in London and/or as a company car there are additional savings and tax benefits to be considered.

⁴⁸ Based on conversion rate of £1= €1.25. McKinsey & Co, A portfolio of power-trains for Europe: a fact-based analysis, 2010.

Illustrative running costs for ULEVs compared to petrol and diesel vehicles over three years⁴⁹

	Petrol C Class	Diesel C Class	PHEV	E-REV	BEV	BEV (battery leased)	FCEV ^{*50}
Upfront cost							
Retail price	£15,890	£17,115	£32,465	£33,100	£25,935	£17,793	£53,105
PiCG	£0	£0	-£2,500	-£2,500	-£4,500	-£4,500	-£4,500
VED	£125	£20	£0	£0	£0	£0	£0
Registration fee	£55	£55	£55	£55	£55	£55	£55
Total upfront cost	£16,070	£17,190	£30,020	£30,655	£21,490	£13,348	£48,660
Running cost (36,000miles/3 years)							
Battery leasing	£0	£0	£0	£0	£0	£3,348	£0
Fuel	£4,716	£3,525	£2,118	£1,446	£1,449	£1,215	£3,998*
Insurance	£802	£1,050	£986	£975	£977	£654	TBC
Servicing	£570	£570	£447	£225	£327	£225	£450
Total running costs	£6,088	£5,145	£3,551	£2,646	£2,753	£5,441	£4,448
Total cost of ownership (over 3 years)							
Total upfront costs	£16,070	£17,190	£30,020	£30,655	£21,490	£13,348	£48,660
Total running costs	£6,088	£5,145	£3,551	£2,646	£2,753	£5,441	£4,448
Residual value	-£6,375	-£6,454	-£10,145	-£12,531	-£8,340	-£6,723	TBC
Total cost of ownership	£15,783	£15,881	£23,426	£20,770	£15,903	£12,066	TBC
Additional information							
CO ₂ g/km	136	109	49	13	0	0	0
Insurance group rating	11	11	16	21	23	15	TBC

* only applies to the Toyota Mirai as of 1/3/2016

** Assuming hydrogen priced at £7/kg.

3.4 What is the residual value, or the second-hand price, of an ULEV?

The residual value will depend on a number of factors. For example, if ULEVs prove to be reliable, practical and popular then they could retain at least 40% of the original purchase price after three years.

Although other AFVs currently on the market have set a good precedent with high residual values there is no consensus opinion on residual values for ULEVs.

Two of the largest residual value companies, CAP and Eurotax Glass's Guide, have published ULEV residual values which are competitive with similar sized ICE vehicles. It is anticipated that there will be a strong demand for ULEVs when they become more widely available on the used car market. Glass's has shown that used EVs did not suffer from higher depreciation in absolute terms compared to equivalent petrol engine vehicles.⁵¹ Some vehicle manufacturers offer protection of residual values.

⁴⁹ This chart and the figures are courtesy of Go Ultra Low.

⁵⁰ These are figures estimates provided by an FCEV model available in the UK at the time of writing. It is also worth noting that there aren't any C class FCEVs currently available and that these are larger vehicles.

⁵¹ SMMT Electric Vehicle Working Group, 18 September 2014.

Tesla, for example, guarantees its Model S will have residual value after three years of at least 50% of the base purchase price plus 43% of the original purchase price for all options including upgrade to the 85kWh battery pack.⁵²

3.5 Can I lease an ULEV?

A number of leasing companies in the UK can offer you advice on the leasing costs of an ULEV. It is also possible to rent an ULEV.



Incentives and tax

3.6 What incentives are in place for ULEVs in the UK?

At national level, the government is offering a grant towards the cost of an eligible ULEV, through the PiCG.

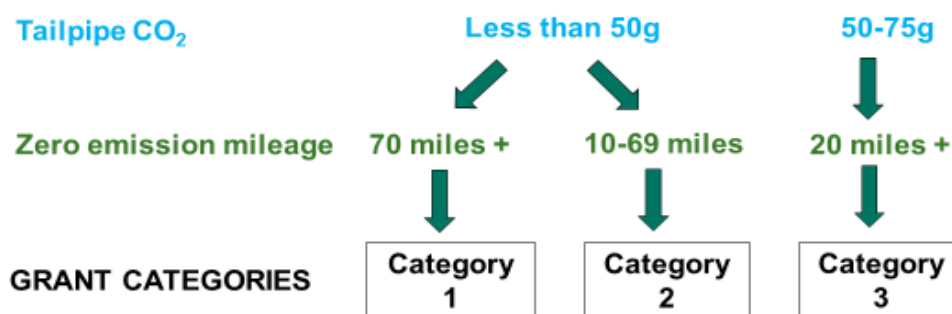
To be eligible for the PiCG, vehicles must meet specific requirements, including the following:

- Only new vehicles of category M1 (passenger cars).
- Vehicles must emit less than 75g CO₂/km.
- Battery Electric Vehicles (BEVs) must be able to travel a minimum of 70 miles between charges. Plug-in Hybrid Electric Vehicles (PHEVs) must have a minimum electric range of ten miles.
- Vehicles must be able to reach a top speed of 60 miles/hour.
- Vehicles must have a three year or 60,000 vehicle warranty and a three year battery and electric drive train warranty, with the option of extending the battery warranty for an extra two years.
- Vehicles must have either a minimum five year warranty on the battery and electric drive train as standard or extra evidence of battery performance to show reasonable performance after three years of use.
- Vehicles must comply with regulations (UN-ECE Reg 100.00) that demonstrate they are electrically safe.
- To ensure they are safe in a crash, vehicles must either have a European Commission Whole Vehicle Type-Approval (EC WVTA, not small series) or evidence that the car has appropriate levels of safety as judged by international standards.

From 1 March 2016, the following rates apply:

- £4,500 for eligible Category 1 vehicles
- £2,500 for eligible Category 2 vehicles
- £2,500 for eligible Category 3 vehicles

⁵² See http://my.teslamotors.com/sites/default/files/pdfs/20150408_rvg_gb.pdf



The grant will be maintained at these levels until March 2018, or until a prescribed number of each type of vehicle have been sold, or whichever is sooner.

The trigger points for a further review of grant levels will be 40,000 Category 1 vehicles, and 45,000 combined sales of Category 2 and 3 vehicles, with both totals including cars sold before March 2016. As of December 2015 23,000 claims had been submitted for Category 1 vehicles and 28,000 claims for Category 2 and 3 vehicles.

To encourage zero emission vehicles and maximise the number of everyday motorists who can benefit, a price cap for Category 2 and 3 vehicles will operate from 1 March 2016. **Vehicles that cost £60,000 and above will no longer be eligible for the grant.** There will be a derogation for Category 1 vehicles, which will remain eligible for the full grant.

More information is available on www.gov.uk/olev.

Current tax incentives for BEVs, PHEVs, E-REVs and FCEVs include:⁵³

- Vehicle Excise Duty exemption
- Fuel Duty exemption on electricity and hydrogen for FCEVs
- Enhanced capital allowances
- No Company Car Tax (Benefit in Kind)⁵⁴

In the summer of 2015, the government released new Vehicle Excise Duty (VED) rates that will come into place on 1 April 2017. New bands are to be introduced; cars registered after 1 April 2017 will be categorised into three bands: zero, standard and premium.

The First Year Rates (FYR) of VED will vary according to the CO₂ emissions of the vehicle. A flat standard rate of £140 will apply in all subsequent years, except for zero emission cars, where the standard rate will be £0. Cars with list price above £40,000 will attract a supplement of £310 on their standard rate for the first five years in which it is paid. All cars first registered before 1 April 2017 will remain in the current system, which will not change.⁵⁵



⁵³ Further information on these incentives can be found at: www.hmrc.gov.uk/index.htm

⁵⁴ <http://www.hmrc.gov.uk/cars/rule-changes.htm>

⁵⁵ See <https://www.gov.uk/government/publications/vehicle-excise-duty>

New Vehicle Excise Duty system for cars registered from 1 April 2017

Emmissions (g/CO ₂ /km)	First year rate	Standard rate*
0	£0	£0
1-50	£10	£140
51-75	£25	£140
76-90	£100	£140
91-100	£120	£140
101-110	£140	£140
111-130	£160	£140
131-150	£200	£140
151-170	£500	£140
171-190	£800	£140
191-225	£1200	£140
226-255	£1700	£140
Over 225	£2000	£140

*cars over £40,000 pay £310 supplement for five years

Local level incentives to encourage the use of ULEVs are also being offered in some areas. These might include, for example:

- Free or subsidised parking
- Free electricity from public recharging infrastructure (limited)
- Exemption from paying the Central London Congestion Charge⁵⁶
- Access to bus lanes

More information about incentives on offer in a specific area can be obtained by contacting the relevant local authority or transport authority.

3.7 Are there any incentives or grants to install a chargepoint at home?

To help private plug-in vehicle owners offset some of the upfront cost of purchase and installation of a dedicated domestic chargepoint, the government runs an Electric Vehicle Homecharge Scheme. This enables customers who are the registered keeper, lessee or have primary use of an EV to receive a grant for the capital costs of the chargepoint and associated installation costs.⁵⁷ Details of current grant levels are available on www.gov.uk.⁵⁸

3.8 Are there any investment opportunities in the ULEV industry?

Plenty – it's a growth market with new elements in the value chain, including vehicles, components, infrastructure, utilities, renewable energy generation, telematics, system networking, back office support, retailing, service and parts supply.

In addition, the UK is at the forefront of ULEV industry development, for example, many world class ULEV technologies have been demonstrated in the UK. A number of British ULEV products and services are experiencing international demand, and significant investment has been committed by major manufacturers to produce and sell ULEVs in the UK. This high degree of activity has increased the rate of progress in the UK industry and has multiplied the number of investment opportunities.

⁵⁶ <https://tfl.gov.uk/modes/driving/congestion-charge>

⁵⁷ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/418525/electric-vehicle-homecharge-scheme-guidance-for-customers-2015.pdf

⁵⁸ <https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-guidance-for-customers-2015>

CHAPTER 4

ENVIRONMENT

Emissions, electricity and the grid

4.1 Will an increase in ULEVs lead to more emissions from electricity generated by fossil-fuelled power stations?

Electric vehicles are more efficient than ICE vehicles. Electricity generation, even where this is fossil fuelled, is on the whole relatively more efficient, emissions-wise, than ICE vehicles. This is primarily because a significant proportion of fossil fuel generation is natural gas fired. This fuel has lower carbon intensity than petrol or diesel.

These factors result in EVs having significantly lower emissions than ICE vehicles even under current electricity grid carbon intensity. This is borne out by various lifecycle studies. Furthermore the carbon intensity of the grid is expected to reduce over time as coal power plant retire and additional low carbon generation becomes available in response to government policy. Thus it could be inferred that an increase in ULEVs is not as likely to lead to an increase in overall emissions as a similar increase in ICE vehicles.⁵⁹



In the first quarter of 2015, around 41.4% of UK electricity was generated from low carbon sources, showing a rise from 37.3% in 2014⁶⁰ (22.3% renewable energy, 19.1% from nuclear⁶¹). To minimise net carbon emissions, it is important that most charging takes place outside peak hours (peak demand is between 18:00 and 22:00, off peak hours run overnight). The proportion of coal and gas-fired power generation is lower overnight, so an EV charged overnight effectively has lower 'well-to-wheel' emissions than one charged during peak hours.⁶²

4.2 Why, according to some sources, do ULEVs produce approximately 80g CO₂/km? ⁶³

The metrics for determining vehicle emissions have always been tailpipe emissions, so-called 'tank-to-wheel'. ULEVs have no emissions at the point of use when powered solely by battery or by hydrogen through fuel cell stacks.

The reference to 80g CO₂/km is based on a 'well-to-wheel' analysis, which includes the CO₂ emissions during electricity generation for the UK grid mix and was quoted in the King report.⁶⁴ The King report, however, has not been updated since 2007.

To make a more accurate comparison of emissions from all cars, the 'well-to-wheel' figure is most objective, as it includes CO₂ emissions during production, refining and distribution of petrol/diesel.

⁵⁹ For best case and worst case analyses, see <http://ee.ricardo.com/cms/assets/Documents-for-Insight-pages/Transport/08.-LowCVP-conference.pdf>

⁶⁰ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/437802/Electricity.pdf

⁶¹ Ofgem: www.ofgem.gov.uk/ofgem-publications/76160/13537-elecgenfactsFs.pdf

⁶² Fuel used in electricity generation and electricity supplied, March 2010: www.decc.gov.uk

⁶³ For information: To calculate CO₂ emissions for vehicles which have both plug-in capability and ICE, two tests are run: one with a fully charged battery (Condition A) and one with a fully depleted battery (Condition B). The published CO₂ emission figure is the average of these two figures weighted over a distance equal to the electric-only range of the vehicle plus around 16 miles (25km). No separate urban or extra urban figures are available for such vehicles.

⁶⁴ King review (October 2007), p36, Chart 3.2, <http://www.low-carbon-ktn.org.uk/KingReviewReport.pdf>

The average 'well-to-wheel' emissions for small and medium-sized ICE vehicles sold in the UK in 2014 range between 127.1g and 136.8 g CO₂/km⁶⁵ ('tank-to-wheel' 116.3 g CO₂/km is the UK sales weighted average of A to C segment cars sold in 2014⁶⁶). Not only do pure EVs have zero tailpipe emission but research suggest that, using the current UK power mix, EVs could realise up to 40% benefit in CO₂ savings compared with a typical family petrol car in the UK over the full life cycle.⁶⁷ 2014 figures suggest that energy used per vehicle produced was 2.0 (MWh/unit).⁶⁸

Larger emission reductions will be realised over time as the UK moves to a higher proportion of low carbon sources of power generation.⁶⁹ The continual increase in ULEV registrations is important in contributing to the continual reduction of CO₂ emissions across all vehicle segments.

FCEVs emit no CO₂, although some of the processes for producing hydrogen do. The UKH₂Mobility consortium believes that a hydrogen production mix of about 50% water electrolysis and 50% steam methane reforming would ensure the 'well-to-wheel' for FCEVs would be some 60% lower than comparable ICEs and similar to those of PHEVs.⁷⁰

4.3 How much of our electricity is low carbon?

In 2014, 19.1% of all UK electricity generation came from renewable sources. 19% of electricity was from nuclear power.⁷¹ The UK's renewable energy target under the Renewable Energy Directive (RED), which encompasses all energy uses (i.e. beyond just for transport), is 15% by final energy consumption by 2020, and the Department for Energy and Climate Change's UK Renewable Energy Strategy lead scenario suggests that up to 30% of our electricity could be generated from renewables to meet this target, with the remaining energy coming from renewable heating and transport. Much of this electricity will be from wind power, on and offshore, but biomass, hydro, and potentially wave and tidal electricity generation will also play an important role.⁷²



4.4 Will the grid be able to cope with increased demand?

According to research completed for the government, if most charging takes place in off-peak periods the current grid will be able to cope with new demand from ULEVs.⁷³ Off-peak charging will enable surplus energy to be used, resulting in more efficient use of the electricity generated.

⁶⁵ 127.1g to 136.8g CO₂/km is calculated by adding the average tailpipe emissions of A to C segment cars (116.3g CO₂/km, Source: SMMT MVRIS data) plus the average well-to-tank emission figure, ranging from 10% to 18%, i.e. 10.8g to 20.52g CO₂/km. This is the range suggested by various sources, such as:

- Electric Vehicles In The Context Of Sustainable Development In China (UN Commission on Sustainable Development, 2011, paragraph 57), http://www.un.org/esa/dsd/resources/res_pdfs/csd-19/Background-Paper-9-China.pdf
- Investigation into the Scope for the Transport Sector to Switch to Electric Vehicles and Plug-in Hybrid Vehicles (<http://webarchive.nationalarchives.gov.uk/20090609003228/http://www.berr.gov.uk/files/file48653.pdf>)

⁶⁶ 120g CO₂/km is the UK sales weighted average of A to C ICE engine vehicle segment cars sold in 2014. (Source: SMMT MVRIS data)

⁶⁷ <http://www.dft.gov.uk/pgr/scienceresearch/technology/lowcarbhonelecvehicles/>

⁶⁸ SMMT Sustainability Report: <http://www.smmt.co.uk/wp-content/uploads/sites/2/Summary-1.jpg>

⁶⁹ OLEV

⁷⁰ Sources: OLEV and UKH₂Mobility

⁷¹ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/437802/Electricity.pdf

⁷² DECC; UK Renewable Energy Strategy:

http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx and DfT, Investigation into the scope for the transport sector to switch to electric vehicles and plug-in hybrids, 2008.

⁷³ OLEV report- Ultra Low Emission Vehicle Strategy

Before adding a chargepoint at any site, a competent installer will assess whether the available electrical capacity is sufficient, and they will sometimes need to inform the local distribution network of chargepoints they install. Where local networks are already close to capacity, there may be distribution issues and localised upgrading of the network may be necessary for a future cluster of vehicles charging during peak hours. The installation of most domestic chargepoints doesn't require a new connection to the grid, because the existing connection to that property is sufficient to accommodate the power being drawn.

Electricity companies are working with ULEV manufacturers to prepare for the future. Electricity demand will be managed through the development of smart metering systems which can automatically select charging times, as well as tariffs which incentivise off-peak charging.⁷⁴ These smart grids, alongside the roll-out of electricity and gas smart meters across all domestic properties in Britain by 2020, will contribute to managing demand more adequately.

There are also home battery storage options that will be purchasable in the UK in the near future (Tesla as an example) which will allow solar and off-peak electricity to be stored. This in turn will help reduce the impact on the grid. However, the grid has time to adapt. Even by the most optimistic scenarios for ULEV market growth, electricity demand from ULEVs will not exceed 0.3% of total electricity consumption by 2020.⁷⁵

4.5 What will happen if everyone charges their EV at the same time?



The National Grid manages the grid on a second by second basis to ensure that supply and demand are met and to indicate to the market if there is a shortfall or surplus of power. However, where local networks are already close to capacity, localised upgrading of the network may be necessary for a future cluster of vehicles charging during peak hours.

However, it is likely that drivers will charge at different times, depending on their vehicles and driving patterns. The increase in demand for electricity is unlikely to be entirely an additional load on existing peak generating capacity due to EV owners' preference of when and where to charge their vehicles.⁷⁶ Additional demand for electricity from ULEVs at night also means that energy generated from intermittent sources of supply (renewable) or those which are difficult to vary quickly (nuclear) can be used where they might otherwise have been wasted.⁷⁷

There are also currently studies on grid balancing and distributed systems that investigate the demand EV charging might place on local electricity networks. The My Electric Avenue study, for instance, seeks to understand how the electricity network will cope if EV proliferation increases and residents on the same street plug-in at the same time.⁷⁸ The results of the trial have now been released. For more information, please visit the My Electric Avenue website: myelectricavenue.info/trial-results.

The introduction of smart meters will also help balance the grid, as it will enable electricity suppliers to vary tariffs to either encourage or discourage charging at times depending on whether the power is cheap or plentiful and how much capacity is available in the networks. However, at the end of 2014, just over 400,000 smart electricity meters were in operation in residential homes. This represents less than 2% of all domestic properties. These delays mean that the mass roll-out of smart meters is now expected to begin in the second half of 2016, although it is still expected to meet the 2020 goal.⁷⁹

⁷⁴ As above

⁷⁵ Source: EDF Energy (0.3% - based on 660k plug-in vehicles with an average electric mileage of 7,500 miles)

⁷⁶ OLEV: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/239317/ultra-low-emission-vehicle-strategy.pdf

⁷⁷ Ibid

⁷⁸ SMMT EV Working Group, March 2015

⁷⁹ <https://www.theccc.org.uk/charts-data/ukemissions-by-sector/power/>

4.6 What's being done to decarbonise production of electricity?

The government in 2009:⁸⁰

- set a target of 30% of our electricity from renewable sources by 2020 by substantially increasing the requirement for electricity suppliers to sell renewable electricity.
- stated it would invest £120 million in offshore wind and up to £60 million in marine energy.

The previous government stated that it would:⁸¹

- seek to increase the target for energy from renewable sources, subject to the advice of the Committee on Climate Change.
- continue public sector investment in carbon capture and storage (CCS) technology for four coal-fired power stations.
- deliver an offshore electricity grid to support the development of a new generation of offshore wind power to encourage community-owned renewable energy schemes where local people benefit from the power produced.
- allow communities that host renewable energy projects to keep the additional business rates they generate.

The Energy Act passed in 2013 was introduced to enable reform of the electricity market to support the transition to a low carbon power sector. The Act has driven progress in reducing emissions within the electricity energy sector towards 2020. There was significant progress in 2014, with the emissions intensity of UK electricity falling 12% to 442g CO₂/kWh. This progress is set to continue to 2020. Furthermore, projects under the Electricity Market Reform the Renewables Obligation and small-scale Feed-in Tariffs are helping to increase the renewable electricity share from 19.1% in 2014 to over 30% in 2020.⁸²

4.7 What's happening to reduce carbon emissions from conventional vehicles?

Consumer demand for cleaner technology and EU legislation are a strong driver for change. The latest SMMT CO₂ report shows that average CO₂ emissions from new cars in the UK have fallen by 26.4% between 2007 and 2015. Average new car CO₂ emissions fell by 2.6% from 2014 to 121.4g/km in 2015.⁸³ This shows that the UK fleet of new car sales was 4.2% below the 130 g/km 2015 pan-EU target in 2014. By optimising ICE technology, fuel consumption can be reduced, which leads to a reduction in carbon emissions. In addition, the fossil carbon content of the fuel itself can be reduced in various ways, one of which is by using sustainable biofuels. However, to help achieve the Government's target of an 80% reduction in greenhouse gas emissions by 2050, road vehicles will need to gradually transition towards much lower or even zero tailpipe emissions.

4.8 Will oil companies or large vehicle manufacturers resist the uptake of ULEVs?

The Automotive Council has a clear direction, which includes the continued development of efficient ICEs and the increase in a range of alternative low carbon technologies. Many vehicle manufacturers are investing heavily in the design, development and production of ULEVs. Manufacturers and governments around the world are working together to speed up the development of low carbon vehicles. Oil companies, too, are engaged in the plans. For example, Shell and BP are heavily involved in work by the Energy Technologies Institute (ETI) which develops and tests the pathways to a self-

⁸⁰ The Committee on Climate Change (CCC) is an independent body established under the Climate Change Act to advise the UK government on setting carbon budgets, and to report to Parliament on the progress made in reducing greenhouse gas emissions. www.theccc.org.uk

⁸¹ HM government, Low Carbon Transition Plan: National Strategy for Climate and Energy, 2009.

⁸² http://www.cabinetoffice.gov.uk/media/409088/pfg_coalition.pdf

⁸³ <https://www.theccc.org.uk/charts-data/ukemissions-by-sector/power/>

⁸⁴ SMMT New Car CO₂ Report 2016

sustaining mass-market for plug-in vehicles.⁸⁴ Shell is also involved in the development of HRSs in the UK.



4.9 What happens to the ULEV at the end of its life?

All battery suppliers must comply with The Waste Batteries and Accumulators Regulations 2009. This is a mandatory requirement, which means manufacturers must take batteries back from customers to be reused, recycled or disposed of in an appropriate way. In addition, European legislation (End of Life Vehicle Directive 2000/53/EC) ensures that manufacturers of cars and light vans (including ULEVs) have 85% of the vehicle re-used, recycled or recovered at the end of its life. This will rise to 95% recovery by 2015.

While lead from lead acid batteries is the world's most recycled material (over 90% of all batteries), the volume of lithium recycling is still very small at the moment. Lithium-ion cells are considered non-hazardous but they contain elements that can be recycled. These include metals (copper, aluminium, steel, manganese, cobalt, lithium and iron) as well as plastics.

Authorised treatment facilities (ATFs) carry this out by stripping the vehicles after de-polluting them of all environmentally hazardous components such as batteries, tyres and oil. The ELV Directive also ensures good product design to avoid the use of harmful heavy metals, increase the use of recycled materials and designing them for reuse or recycling.

The RRR (reusability, recyclability, and recoverability of vehicles) Directive 2005/64/EC takes this a stage further, requiring manufacturers of cars and light vans introduced after December 2008 to be 85% reusable and/or recyclable and 95% reusable/recoverable by mass.

In addition, ULEV batteries could have significant value after automotive use. Various organisations are exploring ways in which these batteries could be re-used such as extra domestic electricity storage where the battery could work in conjunction with a home solar panel to store electricity, or utility companies using batteries to store renewable electricity on a larger scale.

4.10 Will ULEVs significantly impact on CO₂ emissions over the next ten years and solve the climate change problem?

A recent report by the Committee on Climate Change suggests that the change over this period will be modest. However, as the grid becomes cleaner so do all the vehicles recharged from it and, as a result, the benefit is cumulative. The Committee on Climate Change has also stated that the widespread

⁸⁴ www.energytechnologies.co.uk

uptake of ULEVs is necessary if carbon reduction targets beyond 2030 are to be met.⁸⁵ The gradual replacement of fleets will play an important role in this.

4.11 Are ULEVs the only way of reducing automotive CO₂?

No, but much can be achieved by choosing the most fuel-efficient model (and therefore least CO₂-emitting vehicle) in a given class of vehicle. Reducing the mileage driven and learning and putting into practice an economical driving style will also significantly reduce CO₂ emissions at the tailpipe, as will ensuring the vehicle is properly and regularly maintained. In addition to ICE developments and the increase in low carbon vehicles, a range of technologies will be introduced by manufacturers to reduce emissions. For example, reducing the weight of vehicles lowers the emissions, whichever fuel is used, simply by requiring less energy to propel the vehicle. Using alternative fuels, such as bio-diesel, are other ways to reduce emissions. However, ultimately, to meet the Government's target of an 80% greenhouse gas emissions reduction by 2050, cars and vans will need to transition towards much lower or even zero tailpipe emission technologies such as BEVs and FCEVs.



4.12 If there are more ULEVs on the road will congestion become worse?

ULEVs are not expected to affect the total demand for cars. Generally, it is expected that when customers are considering buying a new vehicle they will replace their current car with either an ULEV or an ICE vehicle, depending on their requirements. In urban areas in particular, people are encouraged to make use of other modes of environmentally friendly transport such as public transport, walking and cycling.

Batteries

4.13 How are batteries recycled?

Battery contents – lithium, metals (copper, aluminium, and steel), plastic, cobalt and lithium salts – can be recovered by recycling.

Various methods can be used:

- **Hydrometallurgy:** mechanical treatment, separation and grinding. Hydrometallurgy with acid route and complementary electro-chemical process.
- **Thermal treatment (distillation and pyrolyse):** deactivated, crushed, ground. Powders are treated by a hydrometallurgical process to separate lithium and cobalt.
- **Vacuum-distillation:** metallurgical treatment of sorted, pre-treated batches: separation of battery containing metals by vacuum distillation of heavy metals (Cd, Zn, etc).

⁸⁵ https://www.theccc.org.uk/wp-content/uploads/2015/06/6.738_CCC_ExecSummary_2015_FINAL_WEB_250615.pdf

- **Pyrometallurgy:** The pre-sorted batteries are neutralised and crushed, or smelted. The components such as ferrous metals, non-ferrous metals, cobalt, manganese oxide and plastic are separated and returned to the raw material recycle.

4.14 Where does lithium come from?

The main sources of lithium for ULEV batteries are brine lakes and salt pans, which produce the soluble salt lithium chloride. The main producers of lithium are South America (Chile and Argentina), Australia, Canada and China. Lithium could also be extracted from sea water, but this is not commercially viable at current lithium prices.

4.15 How secure is the supply of lithium?

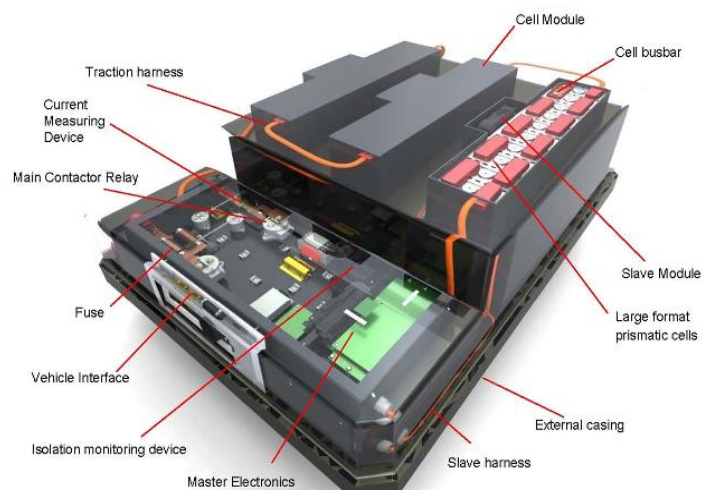
Current estimates of worldwide lithium reserves show an estimate of 150,000 tonnes a year usage with 13 million tonnes of lithium reserves.⁸⁶ Approximately 0.1-0.13kg of lithium is required per kWh of battery storage. Lithium consumption increased by a rate of 10% per year between 2000 and 2008. The expected battery market for ULEVs is expected to grow substantially (up to 28% pa) to 2020.⁸⁷

However, going forward it is expected that the recycling of lithium batteries will become more cost-effective, as in the case of mobile phone and the recycling of laptop batteries. In addition, ULEV batteries have significant value after automotive use. Vehicle manufacturers are exploring ways in which ex-ULEV batteries could be used after automotive use, such as storing home solar-generated electricity, or for utility companies to store electricity on an industrial scale.

4.16 How can we obtain lithium without harming the environment?

Lithium refineries are a 'closed circuit' system, which means that salts precipitated in the evaporation pools are returned to the brine, minus the lithium that has been extracted. Brine extraction takes advantage of the fact that lithium is leached from certain volcanic rocks and, when the surface or ground water flows into closed basins, becomes more concentrated.

The lithium is recovered after the brine is concentrated by solar evaporation, and the alkalines are removed by precipitation. Evaporative brine mining has less environmental impact than hard rock mining and very little carbon footprint. It does, however, use more water than traditional mining methods.



⁸⁶ www.forbes.com/sites/greatspeculations/2015/03/6/teslas-lithium-supply-constraints-might-hamper-its-growth

⁸⁷ Ibid

4.17 What is the environmental impact of battery manufacture and disposal?

It is difficult to give a precise answer on the environmental impact of battery manufacture. However, lithium ion batteries have a lower environmental impact than other battery technologies, including lead-acid, nickel-cadmium and nickel-metal-hydride.

Lithium ion cells are composed of much more environmentally benign materials; in particular they do not contain heavy metals (e.g. cadmium) or compounds that are considered toxic, e.g. lead or nickel. Lithium iron phosphate is essentially a fertiliser. Clearly, as more recycled materials are used the overall environmental impact is reduced.

CHAPTER 5

TECHNICAL

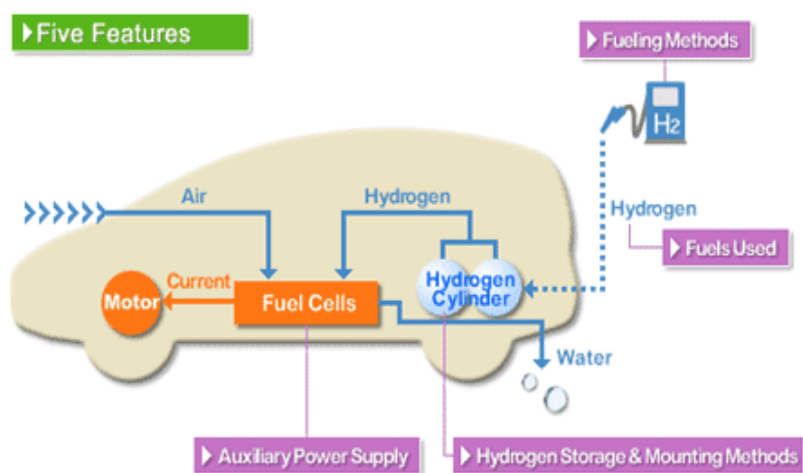
5.1 Are ULEVs safe?

Yes, as with ICE cars, there is specific legislation to ensure that ULEVs are safe. All ULEVs type-approved in Europe have to comply with these regulations.

ULEVs qualifying for the PiCG must meet the same safety standards as conventional cars by obtaining whole vehicle type approval. Alternatively, manufacturers can provide evidence that the car complies with appropriate international safety standards. Particular attention is paid during crash testing to ensure the ULEV-specific safety features operate as specified. Individual components such as the battery pack are also subjected to impact testing and other abuse tests. The first pure electric car was put through the Euro NCAP test in February 2011.

ULEVs typically use an inertia switch or a signal from the airbag system to disconnect the electrical traction supply if the vehicle is involved in a collision. This is very similar to conventional vehicles where an inertia switch is provided to stop the fuel supply in a crash. Furthermore, battery packs are designed with internal contactors so that if the 12V electrical supply is cut for any reason, the traction electrical supply is automatically shut off.

FCEVs are also safe. Despite hydrogen being an energy-dense gas, as a fuel it requires the application of fuel-specific safety controls, just like petrol and diesel.⁸⁸ Whole vehicle type approval includes tests and requirements to ensure the safety of hydrogen fuel systems. Currently, however, commercial operators of tunnels or enclosed or underground car parks may prohibit hydrogen fuelled vehicles.



5.2 Will ULEVs produce any sound?

ULEVs are quieter than ICE vehicles because an electric motor produces much less noise than a conventional engine. This has the potential to reduce sound levels, particularly in noisy cities.

Although ULEVs still generate tyre noise, which is sufficiently loud to alert pedestrians to a vehicle's presence at speeds above 12mph,⁸⁹ the issue is also of interest to visually impaired people. Vehicle

⁸⁸ <http://www.hyfive.eu/hydrogen-and-fuel-cells/>

⁸⁹ Source: Green Car Reports (www.greencarreports.com)

manufacturers, government transport authorities and psycho-acoustic scientists are conscious of these factors and are researching whether artificially generated sounds are necessary for road user safety.

5.3 Does any part of or the whole vehicle need CE certification?⁹⁰

A CE mark certifies that a product has met EU consumer safety, health or environmental requirements. At present the charger needs CE certification as per the Low Voltage Directive. United Nations Economic Commission for Europe (UNECE) Regulation 100 ensures that the vehicle does not require CE certification and therefore is not classified as an electrical appliance. EU requirements for vehicle safety and environmental performance are instead covered by the whole vehicle type approval regime.

5.4 Are there suitable tests to validate performance claims by ULEV manufacturers (i.e. 60 mph and the 100 mile range)?

As with any vehicle, ULEV range depends on a number of factors, such as driving style, traffic, environmental conditions and the use of auxiliary systems in the vehicle. Performance claims should be seen as an indication of the capabilities of the vehicle but some of the performance indicators may involve trade-off; for example, as with ICE vehicles, maximum range is unlikely to be achieved in a usage style based on rapid acceleration, high speeds and heavy use of auxiliary systems such as heating and air conditioning.



Specifically for ULEVs, UNECE Regulation 101 measures range, and the result of the electric energy consumption must be expressed in Watt hours per kilometre. The test uses the same driving cycle as that which is used for measuring the fuel consumption and CO₂ of combustion-engined cars.

The most efficient driving style for an electric vehicle, similar to conventional vehicle technology, is to maintain smooth and progressive driving.

The efficiency difference between an ULEV and a conventional vehicle is most apparent where frequent stop-starts such as inner city driving or in hilly areas characterised by long downhill coasting where the ULEV is able to store the energy normally lost through braking and deceleration.⁹¹

⁹⁰ CE Certification is a mandatory conformance mark on many products placed on the single market in the European Economic Area (EEA). The CE marking certifies that a product has met EU consumer safety, health or environmental requirements.

⁹¹ Cenex EV Range testing presentation Nov 2010:
<http://www.cenex.co.uk/LinkClick.aspx?fileticket=L2mk6XhufzQ%3d&tabid=119&mid=695>

CHAPTER 6

THE MARKET

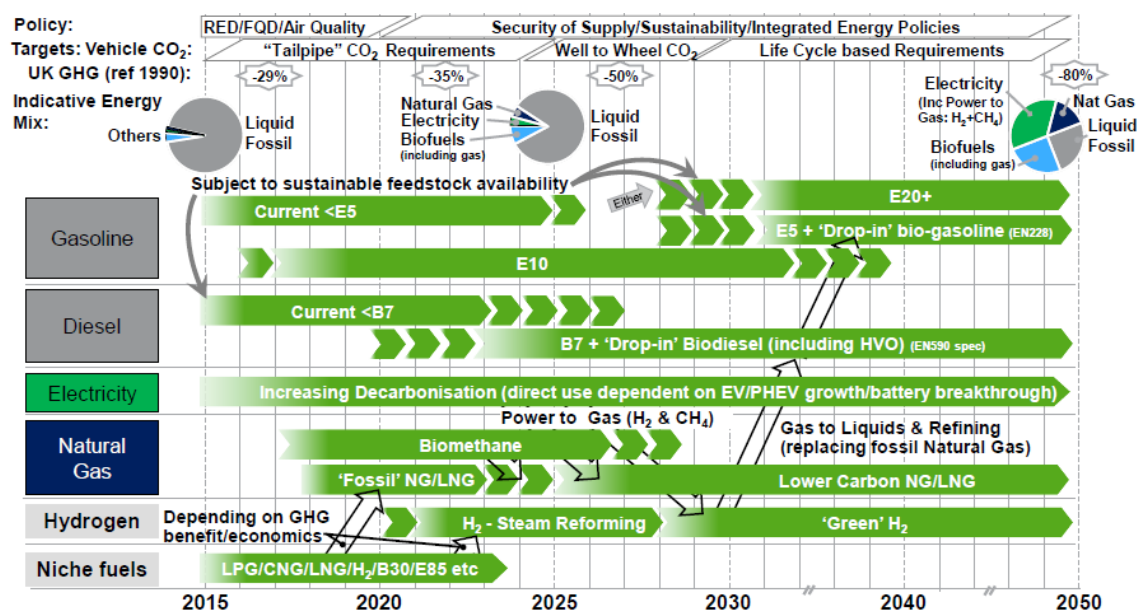
6.1 When will ULEVs be a mass market proposition?

Since 2010, the UK has seen the introduction and production of ULEVs by many of the major manufacturers. ULEV registrations in the UK have increased rapidly since the PiCG was introduced in 2011. Furthermore, the first generation FCEVs are now in the UK market, led by Hyundai's ix35 in 2014 and Toyota's Mirai more recently.

There is movement towards ULEVs being a mass market proposition. A recent report for the Department for Transportation shows that EVs are typically being used as the 'main car' in private owners' households (82%), while 20% of people who own EVs use it as their only vehicle.⁹²

The Automotive Council's recently launched an energy roadmap for passenger cars, commercial and off-highway vehicles is evidence that industry and government are working together to ensure ULEVs follow a mapped pathway towards increased uptake.

The Automotive Council's energy roadmap for passenger cars, commercial and off-highway vehicles



⁹² Uptake of Ultra Low Emission Vehicles in the UK: A Rapid Evidence Assessment for the Department for Transport, May 2015.

6.2 Which ULEVs are on the UK market?*

BRAND	MODEL	TYPE	PiCG ELIGIBILITY
Audi	A3 e-tron	PHEV	Eligible
BMW	i3	Pure EV / E-REV	Eligible
BMW	i8	PHEV	
BMW	225xe	PHEV	Eligible
BMW	330e	PHEV	Eligible
BYD	e6	Pure EV	Eligible
Citroën	CZero	Pure EV	Eligible
Ferrari	La Ferrari	PHEV	
Ford	Focus Electric	Pure EV	Eligible
Ford	Mondeo Titanium	PHEV	
Hyundai	ix35	FCEV	
Kia	Soul EV	Pure EV	Eligible
Lightning Car Company	The Lightning GT	Pure EV	
Mercedes-Benz	B-Class Electric Drive	Pure EV	Eligible
Mercedes-Benz	C350 e	PHEV	Eligible
Mercedes-Benz	S500 Hybrid	PHEV	
McLaren	P1	PHEV	
Mitsubishi	iMiEV	Pure EV	Eligible
Mitsubishi	Outlander	PHEV	Eligible
Nissan	LEAF	Pure EV	Eligible
Nissan	e-NV200	Pure EV	Eligible
Peugeot	iOn	Pure EV	Eligible
Porsche	918 Spyder	PHEV	
Porsche	Panamera S E-Hybrid	PHEV	
Renault	Fluence	Pure EV	Eligible
Renault	ZOE	Pure EV	Eligible
Smart	ForTwo Electric Drive	Pure EV	Eligible
Tesla	Model S	Pure EV	Eligible
Toyota	Mirai	FCEV	Eligible
Toyota	Prius Plug-in	PHEV	Eligible
Vauxhall	Ampers	E-REV	Eligible
Volkswagen	e-Up!	Pure EV	Eligible
Volkswagen	e-Golf	Pure EV	Eligible
Volkswagen	Golf GTE	PHEV	Eligible
Volkswagen	Passat GTE	PHEV	
Volkswagen	XL1	PHEV	
Volvo	V60 D6 Twin Engine	PHEV	Eligible
Volvo	XC90 T8 Twin Engine	PHEV	Eligible

* All data correct as at 1 March 2016

6.3 Which ultra low emission cars are coming onto the UK market and when?*

BRAND	MODEL	TYPE	ESTIMATED UK LAUNCH DATE
Hyundai	Ioniq	PHEV / BEV	2016
Detroit Electric	SP:01	BEV	2016
BMW	740e	PHEV	2016
Tesla	Model X	BEV	2016
Mitsubishi	ASX	PHEV	2016/17
Honda	Clarity FCV	FCEV	2016/17
Vauxhal	Ampera E	BEV	2017

* All data correct as at 1 March 2016

6.4 What are the typical technical specifications of first generation FCEVs on the UK market?

Vehicle Types	
C/D	Family Saloon/estate
E	Executive
J	SUV
Commercial Introduction	
Data	2015
Powertrain	
Power Source	Hydrogen Fuel Cells
Transmission	Electric Motor
Peak power	100kW (135bhp)
Continuous power	75kW (100bhp)
Torque	300Nm (220 lbft)
Fuel	
Pressurised hydrogen gas	
Tank Pressure	70Mpa (700bar)
Capacity	5kg
Consumption (NEDC)	1kg/100km (62miles/Kg)*
Range (NEDC)	500km (320miles)
Performance	
Top speed	160km/h (100mph)
Acceleration 0-100km/h (0-62mph)	12s
Emissions at tailpipes	
Carbon Dioxide	Zero (0gCO ₂ /km)
NOx (Oxides of Nitrogen)	Zero
Sulphur Dioxide	Zero
Particulates	Zero

Chart courtesy of UKH₂Mobility

CHAPTER 7

GO ULTRA LOW

7.1 Go Ultra Low

Go Ultra Low (GUL) is a campaign jointly funded by government and eight vehicle manufacturers to increase purchase consideration of ULEVs. The campaign aims to raise awareness, interest and understanding of ULEVs, establishing them as 'normal not novel' and also to establish GUL as the trusted source of information and advice about ULEVs. GUL is aimed at the end consumer.

7.2 How long has Go Ultra Low been active?

Go Ultra Low was launched in January 2014, originally with five vehicle manufacturers. Since then the coverage and exposure of the campaign has seen it grow from strength to strength

7.3 How can I find out about Go Ultra Low?

Go Ultra Low has an easy to access website, which includes all the specific information that consumers typically look for. There are also links to the vehicle manufacturers involved in the campaign. Please visit www.goultralow.com



